

Status report about COLLAPS experiments and output

(period 2006-2008)

(1) The collaborating institutes

Max Planck Institute, Heidelberg, Germany: K. Blaum (collaboration leader), D. Yordanov
University of Mainz, Germany: R. Neugart, W. Nörtershäuser, M. Schug, J. Krämer, A. Krieger
University of Leuven, Belgium: G. Neyens, M. Bissell, P. Vingerhoets, M. De Rydt, G. Ory,
P. Lievens, M. Avgoulea, K. Flanagan (now at IPN-Orsay)
GSI-Darmstadt, Germany: C. Geppert
University of Manchester, UK: J. Billowes, B. Cheal, E. Mané, F. ...
University of Birmingham, UK: G. Tungate, D. Forrest
ISOLDE/CERN, Geneva, Switzerland: M. Kowalska
University of New York, USA: H. Stroke

Different proposals have been submitted by different collaborations out of these institutes.

(2) Results from experiments (period 2006-2008) and future perspectives.

IS427: Nuclear moments and charge radii of magnesium isotopes from N=8 up to (and beyond) N=20

Collaboration: Leuven (spokesperson), Mainz, CERN, Heidelberg

Proposal submitted in 2003, addendum in 2006.

A detailed status report was submitted to the INTC in May 2008

Summary of experiments in 2006-2008:

- In 2006 we have measured the ground state spin ($I=3/2$), g-factor and magnetic moment of the intruder ground state in ^{33}Mg using a polarized ^{33}Mg ion beam. By combining measurements of the hyperfine structure revealing a negative sign of the magnetic moment with a g-factor measurement using β -nuclear magnetic resonance, we could assign a negative parity to the ^{33}Mg ground state [Yordanov et al., PRL2007].
- In 2007 we have measured the ground state spin ($I=5/2$), g-factor and magnetic moment of the ^{21}Mg ground state near the proton drip line. The same methods were used as for ^{33}Mg . The resulting magnetic moment was compared to its mirror moment in ^{21}F , from which information on the isospin non-conservation effect in these isotopes is deduced [J. Kramer et al., PLB2009, submitted]. We also made a first attempt to measure the isotope shift of some neutron-rich Mg isotopes, but due to several reasons no publishable data were obtained.

Future

- After a status report submitted in May 2008, we received beam time to finish the isotope shift measurements of the neutron-rich Mg isotopes. This experiment is scheduled september 2009. After the analysis and publication of the Mg isotope shifts we consider the project as finished.

IS480: Charge radii of magnesium isotopes by laser spectroscopy: a structural study over the sd shell

Collaboration: Heidelberg (spokesperson), Mainz, Leuven, CERN

Proposal submitted in 2008.

Goal is to measure isotope shifts also for the neutron-deficient Mg isotopes down to ^{21}Mg .

Beamtime scheduled September 2009.



IS439: Nuclear moments, spins and charge radii of copper isotopes from N=28 to N=50 by collinear fast-beam laser spectroscopy

Collaboration: Leuven (spokesperson), Mainz, CERN, Manchester, Birmingham, GSI, New York

Proposal submitted in 2005.

A status report was submitted to the INTC in January 2007.

Summary of experiments in 2006-2008:

- In 2006 we got our first beam time. We measured the hyperfine structures of ^{64,66,67,68g,68m,69,70g}Cu with optical detection of the fluorescence decay of laser-excited Cu beams. From these data, the magnetic moments and spins, quadrupole moments and isotope shifts of these isotopes are deduced. A highlight of this run was the correction to the sign of the ground-state magnetic moment of ⁶⁶Cu bringing its value in line with the systematic of the 1⁺ states in the pf shell when compared to recent shell model calculations. The quadrupole moments of the odd-mass Cu isotopes showed an interesting trend leading to N=40 and showed good agreement with weak coupling calculations. Data are now fully analyzed and papers should be prepared soon (K. Flanagan et al., to be published, P. Vingerhoets et al., to be published).
- In 2007 the main objective of the run was to measure the nuclear spin of ⁷²Cu (found to be I=2) and to establish its single particle structure via its magnetic moment (K. Flanagan, to be published). The secondary goals were to improve the statistical error on the quadrupole moment of ⁶⁹Cu and to measure the quadrupole moment of ⁷¹Cu (done). These measurements showed a significant systematic difference in the isotope shifts when compared to the 2006 data set (now this problem is resolved, after a careful calibration of all voltage dividers on GPS and HRS was done). With these measurements it is now possible to correct the measured voltages from both Run I and Run II and use these data for isotope shift analysis (nearly finished).
- In 2008 the ISCOOL cooler/buncher has been used for the first time to help reduce the fluorescence background in collinear laser spectroscopy measurements. A background reduction of more than 10³ was achieved, allowing measurements of the hyperfine structure of the very exotic Cu isotopes at both sides of the valley of stability. In this run we measured the HFS of the isotopes ^{61,62,68,68m,70,70m1,70m2,71,72,73,74,75}Cu. Overlapping data from previous runs were taken to check isotope shift measurements in light of the systematic error associated with the measured cooler voltage. Data have been analyzed. Highlights from this run are the firm spin-determination for ⁷³Cu (I=3/2) and ⁷⁵Cu (I=5/2), revealing the proposed reordering of the proton single particle levels beyond N=44. A first paper is in preparation (K. Flanagan et al.) and others should follow soon.

Future:

Though beam time is still available to study the neutron-deficient Cu isotopes, we did not request beam time in 2009. First we want to fully analyze the present results and write a few papers. Furthermore, to reach the interesting exotic ⁵⁷Cu isotope, for which we could measure its quadrupole moment and isotope shift (magnetic moment recently measured with in-source laser spectroscopy at Louvain-la-Neuve, T. Cocolios et al.), beam development is needed (intensity and check that there are no molecular contaminants, which could make use of the cooler/buncher impossible). Beam development/test is foreseen in 2009, final measurement in 2010.

IS449: Nuclear charge radius measurements of radioactive beryllium isotopes

Collaboration: Mainz (spokesperson), CERN, GSI Darmstadt, Heidelberg, Tübingen, Ulm

Proposal submitted in 2006, to perform these measurements at ISOLTRAP.

Addendum submitted in 2008, with proposition to move the measurements to the COLLAPS beam line using a collinear/anti-collinear laser set-up to reach the required precision.

Summary of experiments in 2006-2008:

- In 2008 we got two beam times. In an off-line beam time in April we demonstrated the feasibility of frequency-comb based collinear/anticollinear measurements for the accurate

determination of transition frequency measurements on light isotopes with stable ^9Be beam and investigated systematic error sources. Additionally, we could measure the ion beam energy in these measurements and compared them to the nominal voltages of the ASTEC1 and ASTEC2 high voltage supplies. Discrepancies of -12 V and +39 V were observed, respectively (which explained the discrepancies observed in the Cu isotope shift data from 2006 and 2007, taken with different ASTEC voltage dividers). In the on-line beam time in June, we determined the isotope shifts of $^{7,9,10,11}\text{Be}$ and improved the accuracies of the hyperfine splitting in ^7Be and ^{11}Be . The highlight in these measurements is the determination of the charge radius of the one-neutron halo nucleus ^{11}Be (W. Nörtershäuser et al., PRL **102**, 062503 (2009)). Moreover, we recalibrated ASTEC1 and ASTEC2 with the KATRIN 1-ppm high-voltage divider provided by the University of Münster (Ch. Weinheimer). With these calibrations, we could obtain consistent results for the isotope shifts of Cu isotopes measured in 2006 and in 2007.

Future

- Off-line tests with ISCOOL will be performed to check the applicability of the method for the isotope ^{12}Be . These tests will also provide important information for ISCOOL's usage for collinear isotope shift measurements.
- If it turns out to be feasible, we plan to measure the isotope shift of ^{12}Be in 2010.

IS457: Laser spectroscopy of Ga isotopes using the ISCOOL ion cooler/buncher.

Collaboration: Manchester (spokesperson), Birmingham, Leuven, Mainz, CERN, New York, Jyvaskyla, GSI

Proposal submitted in 2007

Summary of experiments in 2007-2008:

- During the summer of 2008, an initial exploration of $^{67-80}\text{Ga}$ was made, measuring the hyperfine structure of these isotopes on two transitions (a 417nm $4p\ ^2P_{3/2} - 5s\ ^2S_{1/2}$ line and a second, 403nm $4p\ ^2P_{1/2} - 5s\ ^2S_{1/2}$ line, to assist in the determination of the nuclear spin values). Despite low photon-ion efficiencies for both of these transitions, the use of ISCOOL to pulse the ion beam critically reduced the photon background by more than three orders of magnitude.

Analysis of the nuclear moments is underway. The spins were measured for ^{76}Ga and ^{78}Ga , where only tentative assignments had been made previously. Additionally, the spin of the odd- A ^{73}Ga ground state was unexpectedly found to be $I=1/2$, despite a firm $I=3/2$ assignment that was made previously.

Future:

The next phase of the IS457 experiment is to extend these initial measurements to study the inversion of ground state spin due to the migration of the proton $f_{5/2}$ level beyond $A=80$. Model-independent mean-square charge radii will also be obtained (beam time in May 2009). Following this experiment, all beam time is used and these results will be published (B. Cheal *et al.* and E.B. Mané *et al.*). In November 2009, we plan to submit a proposal to extend our study to the neutron-deficient isotopes, where the appearance of a proton-halo is proposed, which should be clearly reflected in a strong increase of the mean square charge radii.

IS484: Ground-state properties of K-isotopes from laser and β -NMR spectroscopy

Collaboration: Leuven (spokesperson), Heidelberg, Mainz, CERN

Proposal submitted in 2009.

Beam time approved, not yet sheduled.

(3) The list of publications in refereed journals, 2006-2008

Lecture Notes in Physics 700, 135–189 (2006) (Springer-Verlag Berlin Heidelberg 2006)

R. Neugart and G. Neyens: “*Nuclear Moments*”

General review, not related to a specific IS experiment

Hyperfine Interactions 171, 167-172 (2006)

Proceedings of the LASER conference 2006, Poznan, Poland

M. Kowalska

Mg isotopes and the disappearance of magic $N=20$ – Laser and b-NMR studies

Physical Review Letters 99, 212501 (2007)

“Spin and Magnetic Moment of ^{33}Mg : Evidence for a Negative-Parity Intruder Ground State”

D. T. Yordanov, M. Kowalska, K. Blaum, M. De Rydt, K. T. Flanagan, P. Lievens, R. Neugart, G. Neyens, and H. H. Stroke

Physical Review C 77, 034307 (2008)

“Nuclear ground state spins and magnetic moments of ^{27}Mg , ^{29}Mg and ^{31}Mg ”

M. Kowalska, D.T. Yordanov, K. Blaum, P. Himpe, P. Lievens, S. Mallion, R. Neugart, G. Neyens, N. Vermeulen

Physical Review Letters 101, 132502 (2008)

“Precision Measurement of ^{11}Li Moments: Influence of Halo Neutrons on the ^9Li Core”

R. Neugart, D. L. Balabanski, K. Blaum, D. Borremans, P. Himpe, M. Kowalska, P. Lievens, S. Mallion, G. Neyens, N. Vermeulen, and D. T. Yordanov

URL: <http://link.aps.org/abstract/PRL/v101/e132502>

DOI: 10.1103/PhysRevLett.101.132502

Physical Review Letters 101, 252502 (2008)

“*Masses and Charge Radii of 17–22Ne and the Two-Proton-Halo Candidate ^{17}Ne* ”

W. Geithner, T. Neff, G. Audi, K. Blaum, P. Delahaye, H. Feldmeier, S. George, C. Guénaut, F. Herfurth, A. Herlert, S. Kappertz, M. Keim, A. Kellerbauer, H.-J. Kluge, M. Kowalska, P. Lievens, D. Lunney, K. Marinova, R. Neugart, L. Schweikhard, S. Wilbert, and C. Yazidjian

Nuclear Physics A 799, 30 (2008)

“Nuclear moments and charge radii of argon isotopes between the neutron-shell closures $N=20$ and $N=28$ ”

K. Blaum, W. Geithner, J. Lassen, P. Lievens, K. Marinova and R. Neugart

Physical Review Letters 102, 062503 (2009)

Nuclear Charge Radii of $^{7,9,10}\text{Be}$ and the One-Neutron Halo Nucleus ^{11}Be

W. Nörtershäuser, D. Tiedemann, M. Zakova, Z. Andjelkovic, K. Blaum, M. L. Bissell, R. Cazan, G.W. F. Drake, Ch. Geppert, M. Kowalska, J. Krämer, A. Krieger, R. Neugart, R. Sanchez, F. Schmidt-Kaler, Z.-C. Yan, D. T. Yordanov, and C. Zimmermann

Physics Letter B, in preparation 2009

Ground-state spin and magnetic moment of ^{21}Mg

J. Kramer, K. Blaum, M. De Rydt, K.T. Flanagan, Ch. Geppert, M. Kowalska, P. Lievens, R. Neugart, G. Neyens, W. Nörtershäuser, H.H. Stroke, P. Vingerhoets, D.T. Yordanov

Physical Review Letters, in preparation 2009

Spin and magnetic moments of $^{71,73,75}\text{Cu}$: reordering of quantum levels.

K.T. Flanagan, P. Vingerhoets, M. Avgoulea, J. Billowes, M. Bissell, K. Blaum, P. Campbell, B. Cheal, M. De Rydt, V.N. Fedoseyev, D.H. Forrest, Ch. Geppert, J. Kramer, A. Krieger, U. Koster, M. Kowalska, E. Mane, B.A. March, R. Neugart, G. Neyens, W. Nörtershäuser, G. Ory, J. Rikowska Stone, M. Schug, A. Smolkowska, N.J. Stone, H.H. Stroke, G. Tungate, D.T. Yordanov

(4) PhD and master thesises

Finished:

Deyan Torodov Yordanov, Ph.D. Thesis K.U. Leuven, July 10, 2007

From ^{27}Mg to ^{33}Mg : transition to the "Island of inversion".

Promotor: G. Neyens

Magdalena Kowalska, Ph.D. Thesis Johannes Gutenberg-University Mainz, August 2006

Ground state properties of neutron-rich Mg isotopes – the "island of inversion" studied with laser and beta-NMR spectroscopy

Promotor: R. Neugart

Ongoing:

Ernesto Batista Mane Junior, University of Manchester (july 2009)

High resolution laser spectroscopy of radioactive isotopes using an RFQ cooler-buncher at CERN-ISOLDE

Promotor: J. Billowes

Pieter Vingerhoets, Ph.D. Thesis K.U. Leuven (foreseen 2010)

Moments and charge radii of Cu isotopes from A=61 up to 75: reordering of quantum states.

Promotor: G. Neyens

Dirk Tiedemann, Ph.D. Thesis University of Mainz

Determination of the Nuclear Charge Radii of 7,10 Be and the One-Neutron Halo Nucleus 11Be.

Promotor: W. Nörthershäuser

Monika Zakova, Ph.D. Thesis University of Mainz

Frequency-Comb based measurements of lithium and beryllium isotopes for nuclear structure investigations

Promotor: W. Nörthershäuser

Jörg Krämer, Ph.D. Thesis University of Mainz

The spin and magnetic moment of ^{21}Mg .

Promotor: W. Nörthershäuser

Diploma/Master Thesis

Barend Vervaeke, Licentie thesis, K.U. Leuven, july 2006

Hyperfijnstructuur van stabiel ^{25}Mg en neutronrijke $^{31,33}\text{Mg}$ kernen.

Andreas Krieger, Diploma thesis, Johannes Gutenberg-University Mainz, November 2008

Setup of an iodine-stabilized dye laser for collinear spectroscopy and its application for high-voltage measurements at ISOLDE.

Michael Schug, Diploma Thesis Johannes Gutenberg-University of Mainz, January 2009

Setup and test of a phase sensitive laser frequency long-time stabilization system at COLLAPS

Geoffrey Ory, Master Thesis, K.U. Leuven, july 2009

Onderzoek naar de isotopenverschuiving van neutronrijke koperkernen met behulp van collineaire laser spectroscopie